*On the Relations of the Tertiary and Secondary Rocks forming the Southern Flanks of the Tyrolese Alps near Bassano.** By Roderick Impey Murchison, F.R.S. Sec. G.S. F.L.S. &c. &c.

[From the Annals of Philosophy for June, 1829.]

That various members of the secondary deposits replete with marine remains are found in dislocated positions in some of the highest regions of the Alps, was long ago noticed by De Saussure; and the fact has since been confirmed by many other geologists. The inference derived therefrom, that such remnants can alone have been placed at these heights by elevation from beneath the sea, is now considered by the greater number of observers to be the only philosophical mode of explaining the phænomenon. The object of this memoir is to determine whether the same causes of elevation were applied at a subsequent period to those newer or tertiary deposits which now form a belt around the flanks of the Alps. The solution of this question is called for, because the evidence on this point has hitherto remained so imperfect, that several

* As the interesting communication of Dr. Thom, published in our present number, gives reason to believe, that much curious information will be furnished by a thorough investigation of the Geology of South Africa, we beg, therefore, to recommend to the colonists the collecting of all sorts of rocks or stones bearing any kind of natural impressions or figures, however trifling. In order to shew the character of some formations constituting the flanks of a high mountainous range in Europe, and of the organic remains found in them, we have here reprinted the remarks of Mr. Murchison.—Eds

naturalists are still disposed to adhere to the old opinion, that the forces which gave to the secondary rocks their actual configuration, had entirely ceased to act before the deposition of the tertiary strata. The following sections, which I made last autumn on the southern flank of the Alps near Bassano, appearing to throw light on this curious and important point, no apology is requisite for presenting them to the consideration of geologists; indeed, any details of the structure of distant groups of the tertiary deposits must be considered of high interest when it is stated, that on the sides of the Alps and Apennines they fully rival in thickness our most important secondary formations in England. This particular group, however, near Bassano, is not offered as the type of all the other tertiary deposits of the north of Italy, where their variable characters may still form the subject of other communications from Mr. Lyell and myself.

The tertiary or subalpine deposits, which to the west of the Brenta are so much traversed by basaltic and trap rocks, are entirely free from them in this district between the rivers Brenta and Piave, where they swell into hills of considerable importance, occupying between Asolo and Possagno a breadth of four or five miles. Here, as in many other parts of the north of Italy, they form two great natural divisions:—

1st. An exterior zone composed of conglomerates, with subordinate beds of yellow sand and blue marl, containing shells, the greater number of which are found in the subapennine formations described by Brocchi, and amongst which a considerable proportion of the species are identical with those of the present sea*.

2ndly. An inferior system of green and yellow calcareous sandstone, blue shell marl and compact limestone, some of which are distinguished by nummulites. These latter beds rest upon the scaglia (or equivalent of the chalk), which rising into the Alps passes into a dolomitic limestone of the oolitic series.

Explanatory of these relations, I now proceed to detail two sections in a descending order: the first from Asolo† to Possagno at the foot of the Alps; the second from Bassano to Campese at the mouth of the Canal di Brenta, where that river issues from the Tyrol.

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* This zone is the equivalent of the subalpine conglomerates and marls near Nice, which Mr. Risso was the first to identify with the subapennine formations of Brocchi.

† Fortis in his "Mémoires," vol. i. p. 144, gives a slight sketch of the district of Asolo, but without any attempt to explain its geological relations. He however describes "Madrepora fungites" in blue marl at Castel Cucco; Turbinites terebra and editus of Brander, fig. 47; Dentalium, Murex of ditto; Helix mutabilis, Brander, fig. 58; and other shells in the Val d'Urgana. His figures of the Madrepora fungites are very characteristic.—P. 147.

I. The tertiary conglomerates rise from the plains of Venice, about a mile and a half south of Asolo, at an angle of about 20° to 25°, dip S.S.E.; and to the north of that place they reach to the height of at least seven hundred to eight hundred feet above the level of the Adriatic. The angle of their inclination increases with their altitude; and the mountain torrents flowing from north to south, expose many of these beds dipping even as high as 40° S.S.E.

The boulders contained in these rocks are of very great size towards the exterior of the zone, but they become smaller in the lower beds: some of these boulders are of primary rock, but by far the greater number are referrible to the dolomite of the neighbouring Alps; in the higher beds these are packed together with little or no cementing matter, whilst in the lower they are frequently imbedded in a hard yellow calcareous sandstone forming a compact breccia: still lower there are beds of incoherent yellow sand with some organic remains, and this system may be said to terminate in the escarpments north of Asolo, where a fine conglomerate is seen alternating with beds of blue marl and yellow sand, both containing shells. In the descending series there is no repetition of conglomerates, and the upper system has therefore a well marked termination*.

The lower system is ushered in by a chain of conical hills, the highest beds of which consist of a thick-bedded yellow sandstone charged with green grains, alternating with strong beds of calciferous grits, and dipping under the conglomerates at angles varying from 25° to 30° S.S.E. These contain many organic remains; amongst which are Pectunculi, Pectens, Echini, &c. The surfaces of the beds are further remarkable for the vast quantity of branching stem-shaped bodies resembling Alcyonia. At the base of the escarpment of these hills there is a considerable thickness of blue marl, which is prolonged for about a mile to the north, forming low undulations, the beds of which are exposed on the banks of several streamlets running from west to east The characteristic shells of this marl seemed to be Lucina concentrica (Venus concentrica, *Brocchi*), Lucina mutabilis (Venus mutabilis, *Lamarck*), Echini, &c. North of the small river at Castel Cucco, a compact limestone rises from beneath the marls and attains considerable elevation. The upper beds have a mamillary surface, but upon fracture are of a solid madreporic structure and bluish colour: below this are strong beds of green slaty cal-

* In this respect the order of the strata does not coincide with that which Mr. Lyell and myself observed in the valleys of the Bormida, or at the Superga near Turin, where powerful conglomerates reappear very low in the tertiary series, beneath an enormous development of green slaty micaceous sandstone and shale.

careous grits and yellow sandstone, the latter containing many Pectens, &c.

Succeeding to the above there is a repetition of blue sandy incoherent marls, some beds of which are entirely occupied by vast quantities of a Turritella, highly resembling, if identical with, the T. sinuosa of Bourdeaux; whilst others are filled with the following shells: Natica glaucinoides of the London clay; Solarium approaching to S. canaliculatum, but somewhat differing from the Bourdeaux species; Chama squamosa. Of the London clay, small ostrea, Dentalium grande, &c. &c.

Then follows a yellowish compact limestone with green grains, in strong beds, distinguished by nummulites, oval amygdaloidal concretions of green earth, and alternating layers of blue marl. The limestone succeeding to this has a semi-brecciated fracture, with a pink and bluish tinge*, and is charged with nummulites, &c., the whole alternating with yellow-green micaceous sandstones. The latter repose upon and pass into a calciferous grit containing lenticulites, operculines, cyclolites, and other small multilocular shells, characteristic of the inferior tertiary formations in the north of Italy†.

The escarpment of the lowest part of the tertiary deposits exposed in this section is composed of blue marl, the beds of which have precisely the same S.S.E. dip as the series of nummulite limestone, green sandstone, and conglomerate, previously described; and in a hasty examination the following corals and shells were collected at this spot:—

Caryophyllia altavillensis; Fungites (figured by Fortis, *Mémoires*, vol. i. p. 147); Lenticulites complanata (Operculine of D'Orbigny); Orbitulite (two species); Cyclolites cristata; 1. Nummulites planulata; 2. Nummulites variolaria; Conus stromboides (C. concinnus of *Min. Conch.*); Pleurotoma undata; Fusus longævus; Voluta harpula; Cassis diadema; Serpula spirulæa.

The Alps rise at a rapid angle about half a mile north of the above escarpment; the intermediate low space called the Val d'Urgana, in which flow several torrents from west to east, emptying themselves into the Piave, is choked up with the shivery detritus of the impending secondary rocks, and therefore no junction between the latter and the tertiary is observable. Possagno, ornamented by the magnificent new

* It is in this range of limestone that quarries have recently been opened at Costa lunga, from which have been extracted the principal columns of Canova's splendid new Temple at Possagno. It is a mottled marble, very ornamental, and takes a high polish. Futurity may decide whether this tertiary rock of Europe shall prove as durable a building-stone as that of a similar epoch with which the pyramids of Egypt were constructed.

† In this range of hills lignite is found, which on the authority of Brocchi is imbedded in the blue marl with marine shells.—*Conch. Subap.* vol. i. p. 97.

Temple of Canova, stands upon the first ledges of the scaglia, which rock here rises into the Alps. The upper beds are of a red colour, with some white and green blotches, are very slaty, occasionally contain layers of flint, dip S.S.E. 30° to 35°, and pass downwards into more compact and thick beds, from which variegated marbles are extracted. During my short examination I could detect no organic remains in the scaglia of this district; in which respect, as well as in mineralogical structure, it seemed to be quite identical with the calcarious rock of the Euganean Hills*.

A perfect conformity of dip and bearing of the tertiary to the secondary or ammonite deposits is exhibited in the preceding section; but their junction, as has been stated, is obscured by the denudation in the valley of Urgana, and all along the base of the Alps between Possagno and Bassano it is concealed by vast accumulations of alluvial detritus.

II. The river Brenta, however, in issuing from the Tyrol, cuts transversely through all the deposits from the oolitic series to the most recent, and exposes a most unequivocal junction between the secondary and tertiary rocks, which has not yet, as far as I am aware, been noticed by any geologist. I will describe this section like the former in a descending order.

The youngest beds at Bassano consist of conglomerates, with subordinate and irregular layers of yellow sand, the whole dipping gently away to the plain from the low hillocks on which that town is situated. A little above the bridge the conglomerate forms cliffs on both banks of the river, from fifteen to twenty feet in height, dipping 20° to 25° S.S.E. Ascending the Brenta, and thus approaching the Alps, the lower beds of conglomerate become more highly inclined; and thinning out as at Asolo, they finally pass into yellow sandstone and calciferous grit. The sandstone is micaceous, contains in certain parts many green grains, and hydrate of iron, and the characteristic fossils were Pectens, and other bivalve shells, with Echini, &c. After this the inclination of the strata increases rapidly; and previous to reaching the village of St. Eusebio, the dip already amounts to 40° S.S.E. Green sandstone and blue marl succeed to the above; the surfaces of the more indurated beds being dotted with nummulites, and the marls full of shells similar to those described between Castel Cucco and Possagno. These are most instructively exhibited on the right bank near the village of Sarzon, where the stony

* I am informed by the Marchese Parolini, that in other parts of this neighbourhood the same rock does contain ammonites, belemnites, &c.: for this we have also the authority of Fortis, Maraschini, Professor Catullo, and Dr. Pollini, so that the scaglia may be considered the equivalent of the chalk, a place already assigned to it by Prof. Buckland.

beds having gradually increased their inclination to angles from 70° to 80°, run out like so many walls into the channel of the Brenta; whilst some of the intermediate marls being washed out, the fossilist is enabled, when the river is low, to collect the remains of each layer by inclosing himself between the projecting beds of stone, the upper and lower surfaces of which are thus placed on either side of him. The perfect state of preservation of the shells in these vertical beds is a distinct proof that the dislocation of strata, even when vertical, does not, as some geologists have imagined, necessarily produce any derangement or destruction of their organic contents. These strata mount into a steep hill, on the summit of which is the little church of St. Bovo, at least from six to seven hundred feet above the river, and where they form an outline nearly as peaked and grotesque as that of the adjoining dolomite, or of any other crystalline rocks; thus showing that external form may be entirely due to the inclination of the beds, without any reference to the structure or age of the rock. After passing along the edges of a considerable thickness of blue marly strata, much of which has been swept away by the river, there occurs a very compact brown and pink-coloured limestone, containing small multilocular shells and nummulites. This limestone is the lowest of the members of the tertiary series, and the beds having now become absolutely vertical, are seen in contact with the red scaglia with flints or representative of the chalk, without the slightest appearance of unconformable deposition, the edges of the two formations having a parallel direction from W. to E., as seen in the vertical piers on both sides of the river, on the west bank of which they rise together into a lofty hill.

The upper beds of the scaglia are red and fissile, precisely like those described at Possagno, with flints both in layers and in nodules, and few or no organic remains. The lower beds are thicker and more compact, and gradually losing the red colour, they pass into a beautiful white saccharoid marble, a variety of which is largely quarried (and called Biancon di Pove)*. The vertical edges of this rock are seen for several

* Maraschini, in his "*Saggio Geologico del Vicentino*," is inclined to consider the scaglia a tertiary formation, chiefly because in the districts he examined, it is unconformable to the inferior or Jura limestone. This author's sections, however, were all made in the country west of the Brenta, where the deposits being traversed by a variety of trap rocks, cannot be selected as proofs that the unconformability of the strata is due to any other than a partial cause; for in the district I now describe, and where igneous rocks have *not* penetrated, it has been shown that all the deposits are perfectly *conformable*. But in some of the adjoining regions to the west, and even when intermixed with volcanic rocks, the same deposits are again strictly conformable; and for a full account of these interesting phænomena N. of Verona, I refer the reader to a most able memoir of Dr. Ciro Pollini, "*Lettera Geologica sui Monti Veronesi*." (Biblioteca Italiana, vol. xxviii.)

hundred feet along the right bank of the Brenta; when near Campese it seems to pass into a dolomitic limestone, the beds of which are also vertical and conformable to those of the scaglia. Further in the interior this dolomitic rises into peaks of great height; and for a full knowledge of its mineral characters I refer to the works of Von Buch (*Annales de Chimie*, vol. xxiii.), it being sufficient for my present purpose to state that unlike the older and metalliferous dolomite, which I have described in a notice upon Seefeld near Innspruck*, the rock of this neighbourhood is charged with numerous and very perfect casts of shells of the oolitic series†; whilst in the western parts of the same chain the rock is a true oolitic limestone. In ascending the Canal di Brenta to the source of that river, I found this dolomite occupying the whole region, forming lofty cliffs on both banks, and distinguished by innumerable contortions of its beds, which are inclined at every angle from horizontal to vertical.

Conclusion.—The perfect conformability of the secondary and tertiary strata shown in the preceding sections, whether their mutual angle of inclination be from 30° to 35° as at Possagno, or vertical as in the Canal di Brenta, prove that these several deposits have here partaken simultaneously of some of those great convulsions by which the older rocks of the Tyrolese Alps on which they rest, have been elevated; and the evidence is such, that certain geologists cannot in this instance admit the elevation of the secondary rocks or those containing ammonites, belemnites, &c., and at the same time reject the application of similar disturbing causes to the more recent tertiary deposits; for we see not only the oldest tertiary limestones and marls, but also the most recent conglomerates, rising at very rapid angles to considerable heights.

There is yet much to be learned respecting the order of superposition of the various members of the tertiary formations in different parts of the north of Italy. Brocchi having described the whole of these deposits under the head of Sub-

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Dr. Pollini shows that the Calcaire grossier of Verona rises on the N. of that town to upwards of 3000 feet above the Adriatic; and in its lowest beds passes into, and even alternates with the scaglia or ammonite rock, which in its turn graduates (particularly at the Ponte di Veja) into a subjacent limestone made up of oolitic particles, and charged with fossils of the oolitic series. From these observations Dr. Pollini concludes, that the division of strata into secondary and tertiary formations is merely systematic, and not founded on any natural distinctions; and hence he adopts a new nomenclature of Ultima calcare (Calcaire grossier), Penultima calcare (chalk), Terzultima calcare (oolite). Dr. Pollini, it should further be remarked, states that N. of Verona, nummulites do not cease with the Calcaire grossier in a descending series, but that they occur abundantly in the scaglia, and even as low down as the oolite of the Jura limestone.

* Read before the Geological Society, March, 1829.

† Marchese Parolini has a fine collection of these organic remains in his instructive cabinet at Bassano.

apennine*; and thus formations of the age of our London clay being confounded with those blue marls containing a variety of *recent* shells, it now becomes quite essential to state that the inferior members are essentially different from the superior in zoological contents; it being in the upper beds only that we find a large proportion of shells of the present sea. To this latter epoch belong the conglomerate sands and marls of Asolo and Bassano; and the strata which succeed, offer (amidst the few specimens which my hurried examination permitted me to collect), some species resembling those of the Bourdeaux basin; whilst by far the greater number of the shells enumerated in the oldest members of marl and limestone, near Possagno and on the Brenta, are identical in species with those of the Calcaire grossier of Paris, and the London clay. The lowest beds of this formation both in the north of Europe and in Italy are very similar in containing not only many of the same species of mollusca, but also identical species of nummulites, caryophyllia, &c. Nor can it be urged that the multilocular fossils of these inferior strata are also found in the higher tertiary deposits of Italy, for the microscopic shells of Sienna figured by Soldani differ entirely from those of the Calcaire grossier both in family and species.

Now although we may compare the nummulite rock of Bassano with the Calcaire grossier of the London and Paris basins, we cannot extend the comparison to the subjacent strata: for unlike certain parts of the Paris basin, where a formation distinguished by its freshwater and terrestrial remains is interposed between the Calcaire grossier and the chalk, the plastic clay is entirely wanting near Bassano, and there also the representative of the Calcaire grossier is in conformable apposition to the scaglia or rock containing ammonites†: so that in this portion of the earth's crust we have no trace of any interval of repose between the secondary and tertiary epochs when, as some geologists have imagined, the ocean subsided, and the land was left dry for terrestrial and fresh-water productions to accumulate on its surface;—on the contrary, we here find a continuity of marine deposits or conformable passage from the rocks called tertiary to those named secondary,

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* *Conchiologia Subapennina*, vol. i. p. 97.

† It may be remarked, that the plastic clay is not only absent in the north of Italy but also in most parts of England, and in some situations in France, provided that formation is to be defined as one of *fresh-water* origin. In the Isle of Wight, and at Reading, it is well known that the lowest tertiary beds are exclusively charged with marine exuviæ. If zoological evidence therefore, be considered decisive, the plastic clay cannot be viewed as a distinct and extensive formation resulting from any general cause, but rather as an accidental æstuary deposit, produced by local circumstances.

the only grounds of distinction between the two consisting in the different nature of their organic remains.

It has been mentioned, that to the west of the district described, volcanic rocks are intermingled with the regular deposits. I only made a short excursion in that direction, and near St. Agata and Florian I observed tertiary rocks traversed by amygdaloidal trap and the vitreous basalt of Monte Gloso. These and the contiguous regions further westward are fully described by Fortis and Maraschini, both of whom show that igneous rocks have there burst through and alternated with deposits of different ages. By these numerous vents we may therefore presume, that the expansive forces were finally elaborated, which when confined below may have elevated the neighbouring deposits. I have therefore selected these deposits as types of observation, because they are wholly exempt from the confusion usually incident to any intermixture with volcanic rocks.

List of Organic Remains observed in a cursory Examination of the Tertiary Deposits near Asolo, Possagno, Bassano, &c.

(Named by Mr. James de C. Sowerby.)	Localities in other Parts of Europe.
BIVALVES.	
Ostrea. Several species, all in the younger beds above the blue marl	
Pecten pleuronectes and other species; chiefly in the upper sands subordinate to the conglomerates . . .	Subapennines throughout Italy.
Chama squamaso. Min. Con. Intermediate blue marls	Barton cliff, Hants.
Lucina concentrica, Lam. In the higher beds of blue marl	Placenti, Asti, &c.
——— *mutabilis*, Deshayes, do. do.	Grignon.
UNIVALVES (chiefly in the middle and lower blue marls).	
Rostellaria sinuosa?	Bourdeaux.
Cassis diadema (of Grateloup and Basterot.)	Dax and Bourdeaux.
Conus stromboides (*concinnus* of Sower.) (See Min. Conch. t. 302. f. 2.) . .	Highgate, Barton, and Paris.
Fusus longævus. Min. Conch. t. 63 . .	Lowest beds of Calcaire grossier, London clay, &c.
Melania costellata, Lam.	Paris basin.
Mitra scrobiculata, (*Voluta scrobiculata* of Brocchi)	Placeniia, Sienna, Turin.

Natica glaucinoides. Min. Conch. T. 5.	Highgate, London clay.
——— *globulus* (*Ampullaria globulus* of Deshayes)	Calcaire grossier.
Pleurotoma undata, Lam.	London clay.
———, new species, not yet figured.	
Solarium, approaching to *Sol. canaliculatum*, but differing essentially from the species of Bourdeaux.	
Voluta harpula, Lam.	Grignon.

MULTILOCULAR SHELLS

(in the lowest blue marls).

Lenticulites complanata (*Operculina complanata* of D'Orbigny)	Lowest beds of Calcaire grossier, Beauvais.
——— *variolaria*, Min. Conch. .	Stubbington, in London clay.
Nummulites planulata	Calcaire grossier.
——— *lævigata*	Lowest Calcaire grossier, Beauvais.
——— another species.	———

POLYPIFERS

(in the lowest blue marl).

Fungites, (Lamouroux).	
Orbulites; two species. *Discolites* of Fortis, (see fig. 7. K. & H. pl. II. Mémoires, vol. ii.)	Paris basin.
Cyclolites cristata, Lamarck.	
——— another and more elliptical species.	
Caryophyllia altavillensis, (Defr.) . .	Normandy; Hauteville, Normondy.
Two or three other species of minute corals not identified.	
Echini.	
Serpula spirulæa, (Lamarck).	Bayonne.